



Philosophical Transactions

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PHILOSOPHICAL TRANSACTIONS.

May 23. 1670.

The CONTENTS.

The Answer of Monsieur Marriotte to Monsieur Pecquet, concerning the Principal Organ of Vision; where occur divers considerable Experiments. A Continuation of Dr Edward Brown's Account concerning the Mines of Hungary; where is a particular relation of the Hungarian Copper-mine, together with a Narrative of the many natural Baths in that Country and in Austria. An Account of 3 Books: I. COSMOPOEIA DIVINA, per Ludov. de Beaufort M.D. II. CARTESIUS MOSAIZANS, Auth. Joh. Amerpoel. III. The DIVINE HISTORY of the GENESIS of the WORLD, explicated and illustrated.

The Answer

Of Monsieur Mariotte to Monsieur Pecquet, about the Opinion, that the Choroeides is the Principal Organ of Sight; communicated to the Publisher from Paris, and Englished as follows.

SIR,

I Have in your Answer * seen the reasons, which hinder you from believing that the *Choroeides* is the Principal Organ of Sight; but though they were very Acute, and carried a great deal of Probability with them, yet I did not find them strong enough

* *Vid. N^o. 35. of these Tracts, p. 668, 669, 670, 671.*

enough to oblige me, to grant back again this Preeminence to the *Retina*.

You say, in your *first* Objection, that if the *Sclerotis* and the *Chorooides* be taken away from an Eye that is very fresh, and that the *Retina* be left distended on the Vitreous Humor, one shall not be able to see well through this membrane: whence you conclude, that it is not transparent enough, to let so much light, as is sufficient for vision pass upon the *Chorooides*.

In my opinion, there is good reason to doubt of this consequence, seeing there may be a great deal of difference between the *Retina* of a dead Animal, after it hath been exposed to the Ayre, and that of a living Animal, while it is exactly shut up between the Vitreous humour and the *Chorooides*. Different dispositions do ordinarily change the qualities of things; Fat, which is transparent when it is melted, grows opacous after it is cold again; and the *Tunica cornea* of an Eye being held some hours in ones hand, in a hot Ayre grows thick, and a little after entirely opacous. But to the end you may be perswaded, that the *Chorooides* is sufficiently enlightned in a living Animal, you must take the Eye of an Ox (newly kill'd) while it is hot, and cut it in two, in such manner that a good part of the vitreous humour may remain extended upon the *Retina*; then you shall see distinctly the colours of the *Chorooides*, the basis of the Optick nerve, the trunk of the little vessels which proceed from thence, and their dispersion through the thickness of the *Retina*, with so much perspicuity that you cannot even discern, whether there be a *Retina* beyond the Vitreous humour or no. Hence you may judge, that the light, which the Objects send to the *Chorooides*, is more than sufficient for vision, seeing that being much weakned by the reflexion and by a second passage through the *Retina* and the Vitreous humour, it is yet strong enough to form a clear and distinct vision of the *Chorooides* in our Eyes.

Not that I deny the *Retina* to have some whiteness in a living Animal, and that it is a little less transparent than the other Humours, chiefly in that part which is contiguous to the *Chorooides*; and Nature may have made it so on purpose to temper the brightness of great lights, and to hinder dazeling; in
like

like manner as she hath spread over our skin an insensible *Epi-dermis*, to keep it from being too easily hurt by those bodies that touch us, and by the Excess of heat and cold. But if I should absolutely deny, that the *Retina* hath any opacity in a living Animal, your Experiment would not convince me, it being made but upon a *Retina*, whose more subtle and transparent parts are evaporated; and I might propose to you for an example a piece of white paper, through which, when it is wet, one sees distinctly enough whatever is contiguous to it; and which presently resumes its first opacity, when it is a little while exposed to the Air: And if this Example were not sufficient, I might alledge the little Chrystalline, which is found in the middle of the Chrystalline humour of many Animals, and is as it were the kernel of it; the which, being as transparent as the other humours of the Eye in a living Animal, becomes in two or three dayes after his death white and opacous, notwithstanding that it be left inclosed in the Eye, and that the Exterior Chrystalline remain still transparent.

Your *second* Experiment to prove the opacity of the *Retina*, which is to put it into water, is also extremely deceitful: For, you make no doubt but the *Hyaloeides*, which envelops the Vitreous humour, is perfectly transparent: nevertheless if you lay in a dish half full of water, part of the Vitreous humour, the parts of the *Hyaloeides*, which stick to it, will appear whitish and thick like a spiders web, although the Vitreous humour do still retain its transparency. It is not then a sufficient proof to know, whether the *Retina* be opaque in a living Animal, by putting it into the water: And by what tryal soever you make of it, after it has been exposed to the Ayre, you can draw no consequence to prove that it is opaque in its Natural state: For the Chrystalline it self becomes a little thickish in water, and if it be left there some time, or exposed to the frost, it becomes white and opaque like snow.

It is therefore necessary for resolving our difference, and for knowing with certainty, whether the light of objects pass almost all entire to the *Choroecides*, or whether it is almost all intercepted by the *Retina*, to bring observations made on the *Retina*

and the *Chorooides*, while they are in their natural state, as I shall do in the following Experiment.

Place by night a lighted Candle very near your Eyes, and cause a dog, distant from the candle 8 or 10 paces, to look upon you, then you shall see in his eyes, a light sufficiently bright, which I hold to proceed from the reflexion of the light of the Candle, whose image is painted on the *Chorooides* of the dog, which having much whiteness and luster causes this very strong reflexion; for if it proceeded from the ChrySTALLINE or Retina, the same appearance would be seen in the Eyes of Man, Birds, and other animals, who have the *Chorooides* black, which is not found so by us. It is therefore manifest by this Experiment, that the luminous rayes do pass with a great deal of force as far as the *Chorooides*, and that the *Retina* receives very little impression. Now this appearance is made in this manner: The little picture of the candle which is upon the *Chorooides* of the dog, (where is the *Focus* of the ChrySTALLINE and other humours together) sending rayes back through these humours, makes its reciprocal *Focus* towards the candle, and by consequence the eyes which are near to the point, where these rayes do reunite, ought to see the ChrySTALLINE of the dog very much illuminated. They that are skilled in Opticks know the demonstration: and there is an effect, wholly like unto this, to be seen by a very easy Experiment.

Place around Glass-bottle, full of very clear water, 8. or 10 paces from a Candle, and put behind the bottle, at near the distance of its Semidiameter, a white paper, in such manner that one may see the light of the Candle, which hath passed thorow the bottle, reunited in a little space upon the Paper; then they, who have their eyes near the Candle, shall see the bottle full of light, which will disappear, if you hold the paper either nearer to, or farther from the bottle. And if one hold a small lighted wax-candle in the place of the Paper, and you hold your eye in the place of the former candle, you shall see the bottle yet more enlightned then it was before: And one may easily judge, that the light which appeareth in the dogs eye, proceedeth from a like cause. The same experiment may be made in the

the eyes of several other Animals, and particularly of Cats; in whose eyes this light appears blewish, which shews, that it proceedeth from their *Chorooides* which hath much of this Colour; but this Colour, nor any other which may be in the *Chorooides*, brings no confusion to the Sense of Seeing, for the Senses receive no impression from their own Organs.

The rest of this first Objection hath almost no other foundation, but an interpretation you give to some words of my writing different from my sense; for, when I said, that dark and opaque bodies receive a great deal of impression from the light; I did mean dark and opaque bodies both together; for it had been sufficient for me to name dark bodies, since all dark bodies are opaque; but my thought on this subject was, and still is, that transparent bodies, as the Ayre, the Water, and the Retina in a living Animal, receive *little* impression from light, and that Opaque bodies receive a *great deal*, but that dark bodies receive more then all other Opaque bodies, and the Air and the Water a little less than the Retina.

Nor do I believe, that darkness is absolutely necessary for Vision, but only for a strong vision; nor that the picture of objects ought to be expressed on the Organ of Vision; for, it sufficeth, that the rayes of each point of the Objects be reunited in a distinct and separated point, according as they answer one another; and you will easily agree, that as a Convex glass makes the image of the Sun to appear on white paper with a great deal of brightness and light, and on black paper very obscurely; although black paper (which soon takes fire) receives a great deal more impression than white: So the rayes of illuminated objects do reunite on a whitish *Chorooides*, and express there a visible picture, and on a dark *Chorooides*, a very obscure one, and which cannot be seen; but then the impression is also much stronger in the black than in the white: And this is the cause, why Men and Birds see better and more distinctly then the greatest part of other Animals; for their *Chorooides* being black, and by consequence very sensible of light, they contract much their pupilla or sight-hole of the Eye, which makes the Rayes, that pass there from each point of the Object, to be all very near the

Axis of the Chryſtallin, and to reunite more exactly in a point, then in the Eyes of moſt other Animals, which have their *Chorooides* white towards the *Axis* of Sight, and by conſequence leſs ſenſible of light, who in recompence can very much dilate the Pupilla of their Eyes, when they ſtand in need of a great light; but alſo their Sight is not ſo diſtinct, becauſe the Rayes, which fall on the Extremity of the Chryſtalline, do interſect the *Axis* too near in their refraction.

It is true, that to ſupply in ſome ſort this defect, they have a little Chryſtalline in the middle of the great one, and this little Chryſtalline being of a more ſpifs conſiſtence then the great one, its refraction is alſo more ſtrong, and makes the rayes, which come from one point in the *Axis* and paſs near the Center of the Chryſtalline to refract more then if there had been but one Chryſtalline. And by this means the greateſt part of the Rayes, which fall upon the Extremity of the great Chryſtalline, do interſect the *Axis*; which cauſes their ſight to be leſs confuſed, although it be never ſo diſtinct as that of Men and Birds, which have but one Chryſtalline. *Fishes* have alſo a double Chryſtalline, for otherwiſe their ſight would be more confuſed than that of other Animals who live in the Air, for their Chryſtalline being ſpherical, the rayes cut the *Axis* more unequally than if it were lenticular and its convexities were of a greater ſphere; and it ought neceſſarily to be ſpherical, becauſe the refraction of the Rayes, which paſs from the water into the Chryſtalline, is very ſmall, and would make its *focus* too far diſtant if the Chryſtalline were lenticular.

The difficulty of your *Second* objection proceeds alſo from an Ambiguity of words, and conſiſts in knowing, what we are to ſay it is, that has a great continuity and communication with the Brain. My *Hypotheſis* is, that the Nerves are all coated with the *Pia Mater* (which envelops all the Spinal Marrow) and have with it the ſame continuity of fibers; ſo that if theſe nerves be never ſo little moved, the impreſſion is carried to the Brain by the Continuity of theſe fibers; and whether it be, that the texture is diſferent in Nerves of different ſenſes, or that they contain ſome ſpirituſous liquors which determine their ſen-

sensations, by some differences they have among themselves; it is certain, that the Nerves of Sight, in what manner soever they are moved, represent Colours and Lights; those of Hearing, Sounds, and those of the Touch, Paines, &c.

Now the *Chorooides* is an Expansion and dilatation of the *Pia Mater*, which enveloppes internally the Optique Nerve, and which comes from the tuberosity of the Spinal Marrow, by a continuity of fibres; whence it follows, that how little soever the *Chorooides* be toucht, the impression may be easily communicated to the brain: And to the end, that the same thing may be said of the *Retina*, there must be a little channel in the Optic nerve, through which the Retina in its proper Substance extends it self to this tuberosity by a continuity of Fibers; which is not seen, and you are constrained to say, that there are little filaments of nerves which come from the interior of the Optick, and expand themselves through the Retina, which have this continuity; but if there were these filaments, they should spread themselves through the Retina, as from a Center to a Circumference, and should lye closer together near the Optick nerve, than a good way farther in the Retina: which nevertheless we do not observe to be so.

Besides, if you thrust a pin through the thickness of the Retina, you will often meet with filaments; but if you look on them through a Convex glass, you will discover, that they end in little vessels of Veins and Arteries, which are in the Retina; and infallibly, if there were any nerves, you might find them in the same manner, and they would stop the Pin, since they are as hard and firm as the little Arteries; and when you say, that one may distinguish these filaments in the water, because the rest of the Retina disappears, that is repugnant to experience, and to what you have said before, *viz.* that the Retina may be seen all white in the water, and without transparency; and you ought to shew these filaments, or else we shall take them for a thing invented at pleasure.

You bring after that two Experiments; the *first* of which is, that if an aperture be made on the upper part of the Eye, we may discover the Picture of the Objects on the anterior surface of the *Retina*; but if this aperture be made in the white of the Eye,

Eye; the aqueous humour will run to the *Tunica Cornea*, and make wrinkles, which will hinder the Picture from being distinct: Besides, he that looks in at this aperture, will hinder the Rayes of the Object from passing into the Eye, and he shall see nothing there but his own image. But if you mean, that the *Tunica Cornea* should be wholly taken off, there will not then be distance enough between the *ChrySTALLIN* and the *Retina*, to make the Picture distinct. In conclusion, I do not believe this Experiment can be made, much less that it is to be discerned whether this Picture be formed on the antierour or posterour surface of the *Retina*, since the thickness of it is less than half a line, or the 24th part of an inch; and there is reason to believe, that you have trusted to the report of some other concerning this Experiment; or that you have believed the images which appear in the Eyes to be painted on the *Retina*, whereas they proceed from the reflexion made on the exterior of the *Cornea*.

Your *second* Experiment is true and easie to be made, but according to you it were impossible; for, since you hold, that it is on the antierour part of the *Retina*, that the Picture is seen, and that you have elsewhere said, that one cannot well see through this Membrane, it follows, that you cannot see this Picture through the thickness of the *Retina*; but because I believe, there remains transparency enough in that part of the *Retina* which is not expos'd to the Air, I doubt not but the Picture may be seen on the posterour part of it, after it is become sufficiently opaque, though in a living Animal this Picture passeth as far as the *Chorooides*, as it hath been already proved: and if the *Retina* itself were taken away, and there remained only the vitreous humour, you might notwithstanding see the inverted Picture of the Windows toward the bottom of the Eye, if you held it at the farther side of the room; in the same manner as the Picture is to be seen in the *Focus* of the spherical Glass-bottle fill'd with water, though it seem to be on the exterior surface of the Glass; and by consequence this Experiment proves not the opacity of the *Retina*.

In your *third* Objection you quote, what I said, a little otherwise than I spoke it; for I put in my Writing, that the *Retina* was *about* half a line in thickness, and not half a line *precisely*; which

which shew'd, I had not measur'd it exactly; but if it were but a quarter of a line or less, it sufficeth that it had enough for the effect I did attribute to it: And for another, I did also mention in my Writing, which is, that the Rayes of the same luminous point, which do not unite precisely in the same points in the *Axis*, are rectified by the concavity of the *Retina*, those that are farthest off the *Axis* more than those which are the nearest, which is the reason they unite better in the same point on the *Chorooides*; the which point I hold (with you) to be *Physical*, since the points objective are so too; but I hold it to be lesser than any that can be perceptible to the sight; for we distinguish the different parts of very small objects, as the extremities of the breadth of the little arteries of the *Retina*, which make not an eighth part of its thickness; and that which represents this small breadth, must be 25 or 30 times less in the Organ of our sight, that is to say, in the proportion of the distance of the Object, to the Centre of the sight, and of the distance of this Centre, to the Organ of vision; and by consequence the thickness of the *Retina* is not proper for this smallness.

You see, then Sir, that hitherto your objections have been able but very lightly to shake my opinion, and that the transparency of the *Retina* is well enough established: Let us come now to the proof, I make of the *Way of Vision*, on the Basis of the Optick Nerve.

It must first of all be agreed, that in this Experiment, almost all men do loose sight of an intire circle of white paper, whose diameter is about the 9th or 10th part of its distance from the Eye. Now the visual Triangle, whose Basis is the Diameter of the Circle, and whose top is the Center of vision, is proportioned to the Triangle, whose Basis is the Diameter of the picture of the Circle on the bottom of the eye, and the top, the same center of sight; the which center being distant 6 or 7 lines from the basis of the optick nerve, whose breadth is about $\frac{1}{4}$ of a line, this basis also will be about the 9th or 10th part of its distance from the Center of sight, and by the Principles of Opticks, the Image of the circle of the white paper, falling on the basis of the optick nerve, will cover it precisely; and because the Paper then wholly disappears, it follows, that all the basis

of the Optick nerve is insensible of light; whence I conclude, that the *Chorooides* is the Principal Organ of sight; and that the *Retina* is not, seeing it is placed in that part, and is there apparently disposed in like manner as to the rest of the bottom of the Eye.

To elude the force of this Argument, you alledge other causes of this fault of sight; the two first are almost like one another. But it seems to me, that you suppose them without any ground: for, as I said before, there are no such filaments of nerves to be seen coming out of the basis of the optick nerve; besides, they are not proper for vision, since they would leave in the parts of the Retina too great intervals empty; and its necessary, that every point of the Object find a sensible point in the Organ of sight to unite his rayes there; which is found in the *Chorooides*, which is an Expansion of the sensible part of the nerve into a continued membrane. Besides, the causes of the defect of vision cannot be found in these *Hypotheses*; for in the first, what reason can be given, that there should be no extremities of nerves opposite to the optick nerve. since there would need only a simple direct continuation of some of its fibers unto the Anterior part of the Retina; and for the second (which is the particular opinion) I see not, how the void space in the middle of the inverted Tuft, can comprehend all that extent of the basis whence it proceeds, and why the filaments begin not to receive the impression of the luminous Rayes, but upon the Extrēmy of this basis, since the rayes of a luminous point, which unite themselves in a point at the bottom of the Eye, come from divers points of the ChrySTALLINE, and so, if one part of these rayes were oblique, the other should be perpendicular, and if all the Rayes should fall perpendicular on the Organ of sight, there would be no vision, since there is never but one single Ray of those which unite in a point, that falls perpendicular. But I shall not enlarge my self to demonstrate these impossibilities, since I am perswaded, that these inverted tufts, and these filaments of which they are composed, are but things without a foundation, and which you would have much a doe to shew us.

The other Cause which you bring, is the trunk of the vessels which proceed from the basis of the nerve. Yet you cannot deny

deny but they are very small, and that it is very hard to discern the little holes through which they pass, when the nerve is cut off above its insertion into the Eye; and because they often come out of the basis by two several little holes, the diameter of each of which does not take up the space of above the eighth part of the diameter of the basis; it follows, that if the rest of the nerve were sensible of light, we should not loose sight of a paper of two inches diameter at most, at ten foot distance: and sometimes in fixing one eye on a little piece of Paper, two other, very little ones, separated one from the other, would disappear; which is contrary to experience: for the defect of vision is continued. Seeing then the reasons which you alledge of this defect of sight are either insufficient, or want an assured foundation, it follows, that that which I propose must stand, at least, in respect of any thing you urge against it. And to confirme it yet more, I will adde here some reasons and observations, which are neither in my letter nor in my writing.

The first observation which is very common, is that of the *Pupilla* dilates it self in the shade, and contracts it self in a great light, and it is very hard to find the cause of this involuntary motion, but by the Hypothesis, that the *Chorooides* is sensible of light, for then it is easy to conceive that it being hurt by too strong a vision, it may dilate or contract its fibers, which have one continuity with those of the forepart of the *uvea*, so that it can contract its aperture, and when it is not hurt, relax it again: whereas if the Retina be supposed to be the Organ of sight, it will be very difficult to explain how this contraction is made.

The second is that of the glass bottle full of water, when a lighted candle is placed near its focus: for it is easy to prove that if one hold his hand between the Candle and the bottle, he will feel more heat than if he held it in the reciprocal Focus; that is to say, the place where the Rayes, which have passed thorough the bottle, make a great image of the flame of the Candle appear inverted upon a white surface opposed to it: for I draw this consequence, that the Image of a Candle, which is painted on the *Chorooides* of a dog, as I have prov'd to you, makes a much greater impression on the Retina of the dog, than on that of him that lookes on it and sees it very bright; whence I

conclude that if the *Retina* were the Organ of sight, this dog would not see the objects indifferently inlightned, which are about the candle, although at 3 or 4 foot distance, because they would receive a great deal more impression from this reflexion, and that a great sensation doth obliterate a lesser; which is contrary to experience, and it is not at all likely, there should be such a defect in the sight of Animals.

The third is, that the Eyes of *Birds* are so framed, that the Optique nerve after its insertion into the Eye is inflected, and extends it self on the Concavity of the *Sclerotis* about the breadth of 2 or 3 lines more or less according to the bigness of the Eyes; and the length of this inflection is covered by the *Chorooides*, leaving but one little white streak in the middle, from whence the *Retina* takes its Original, which extends it self on the *Chorooides* through all the bottom of the Eye, but it is covered on the side of this white streak with a little black membrane as long as the inflexion of the nerve, and almost as broad; which proceeds from the *pia mater*, and is as it were an appendix of the *Chorooides*: and if you consider the situation of this membrane, you will find it is near the Axis of sight, and that the rayes of the Objects, which the Birds look on with both Eyes, fall precisely upon it after their refraction. Since then in the place, where Vision ought to be strongest, the *Retina* is covered, and that no man doubts but Birds are more clear-sighted than other Animals; you ought to acknowledge, that the *Retina* is not the principal Organ of Vision, but that that preeminence belongs to the *Chorooides*.

AN ACCOMPT

Given by Doctor Edward Brown, concerning the Copper-mine at Herrn-ground in Hungary.

H*Errn-ground* is a little town, seated very high between two Hills, upon a part of land of the same name, an Hungarian mile distant from *Newsol*. In this town is the entrance into a large Copper-mine, very much digged.

I went in through a *Cuniculus*, called *Tach-stoln*, and continued divers hours in the Mine, and visited many of the most remarkable